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(54) Abstract Title
Digital image scaling with automatic image quality adjustment

(57) A digital image scaling device with automatic image quality adjustment is provided for converting the resolution and frame rate of digital input image data into different resolution and frame rate. The digital image scaling device includes a memory unit for temporary storing the frame data of the digital input image data; a memory access control unit for storing the digital input image data into the memory unit, and for reading th digital input image data therefrom; a plurality of interpolationfunctions for providing various interpolation effects in response to different image quality requests; an interpolation controller for reading a plurality of pixels from the memory unit as referential pixels and for generating digital output image data according to an interpolation function selected automatically from a plurality of interpolation functions using a function sel cting procedure. Since the digital image scaling device of the present invention generates new interpolated pixels using different interpolation functions automatically, the image qualities can be improved and the problems of blurring or blocking effects can be resolved.

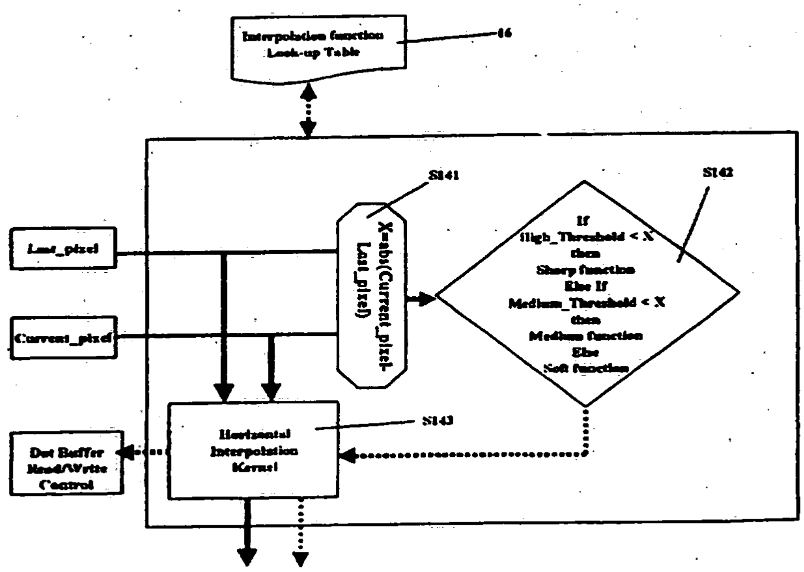

FIG. 5

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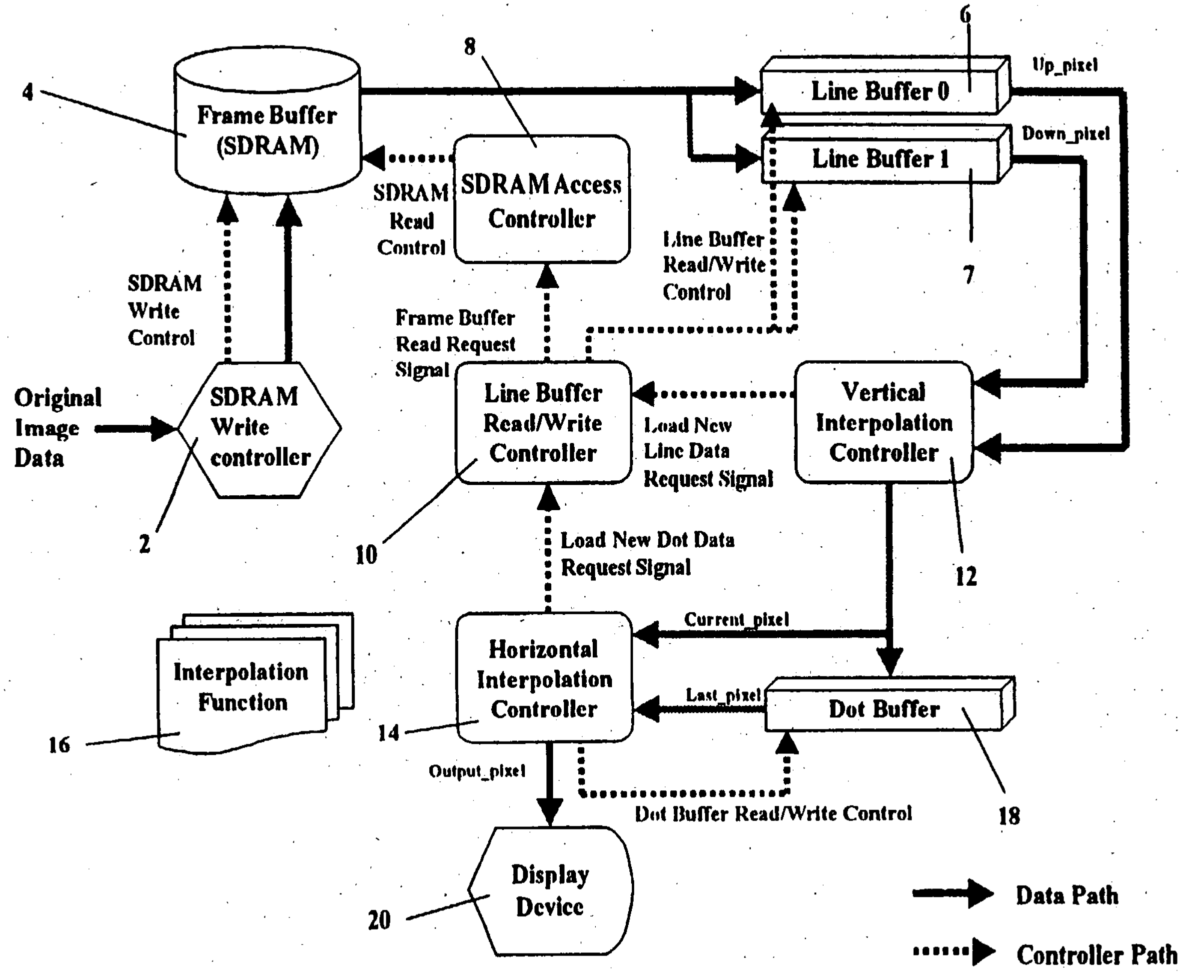

Frame Buffer (SDRAM)
4
8
SDRAM Access Controller
SDRAM Read Control
Line Buffer 0
6
Up_pixel
Line Buffer 1
7
Down_pixel
Line Buffer Read/Write Control
SDRAM Write Control
Frame Buffer Read Request Signal
Original Image Data
SDRAM Write controller
2
Line Buffer Read/Write Controller
10
Load New Line Data Request Signal
Vertical Interpolation Controller
12
Load New Dot Data Request Signal
Current_pixel
Horizontal Interpolation Controller
14
Last_pixel
Dot Buffer
18
Interpolation Function
16
Output_pixel
Dot Buffer Read/Write Control
Display Device
20
Data Path
Controller Path

FIG. 1

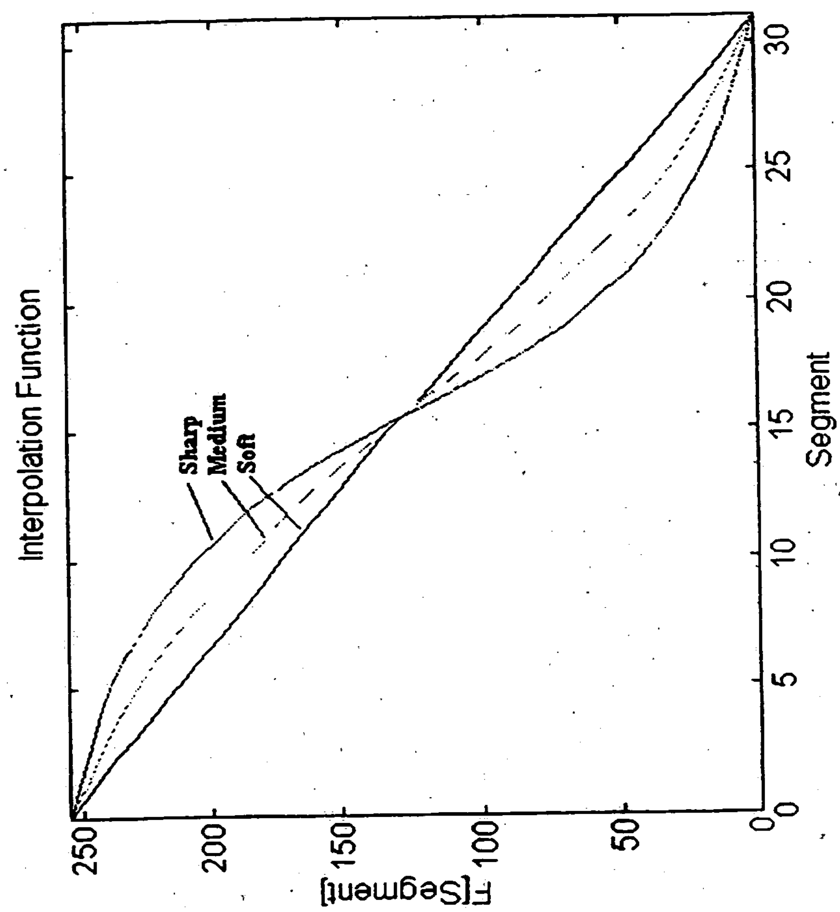

Interpolation Function
Sharp
Medium
Soft
F[Segment]
250
200
150
100
50
0
Segment
0
5
10
15
20
25
30

FIG. 2

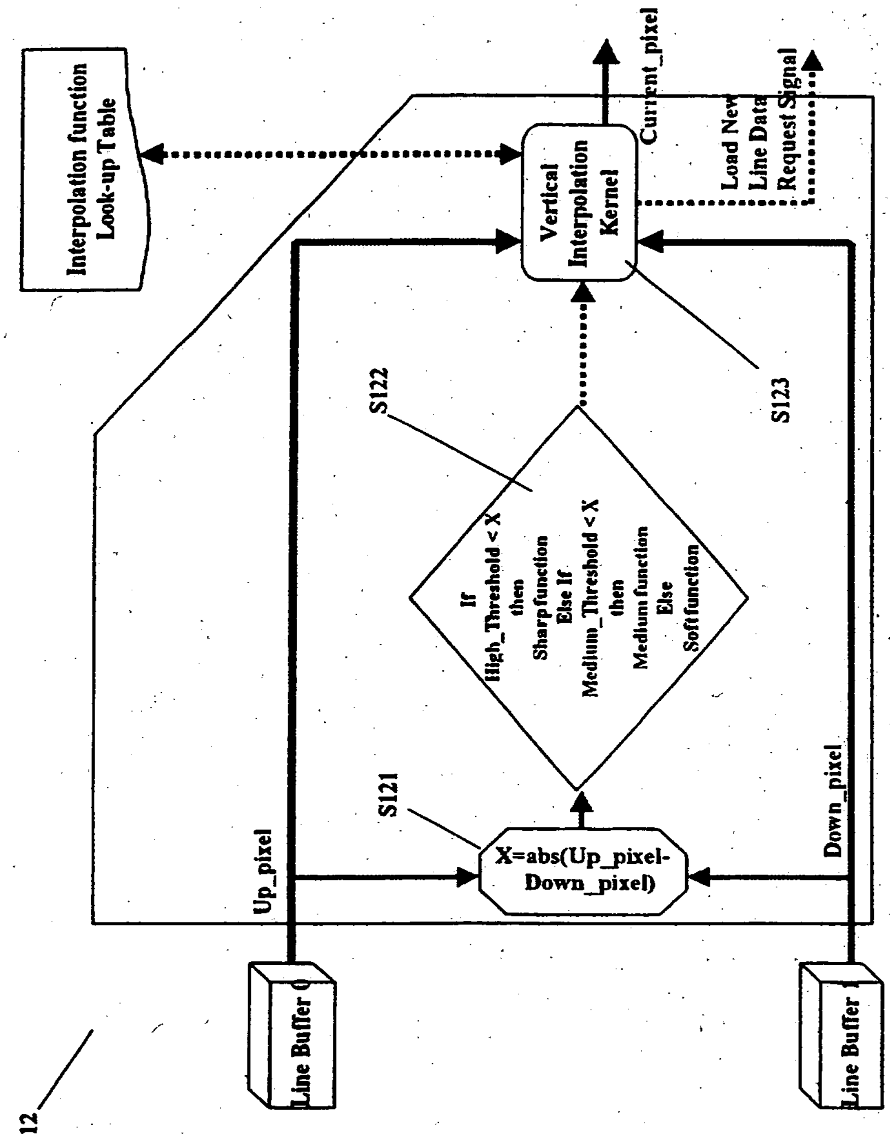

Interpolation function Look-up Table
Vertical Interpolation Kernel
Current_pixel
Load New Line Data Request Signal
S122
S123
If High_Threshold < X then Sharpfunction Else If Medium_Threshold < X then Medium function Else Softfunction
S121
X=abs(Up_pixel- Down_pixel)
Up_pixel
Down_pixel
Line Buffer 0
Line Buffer 1
12

FIG. 3

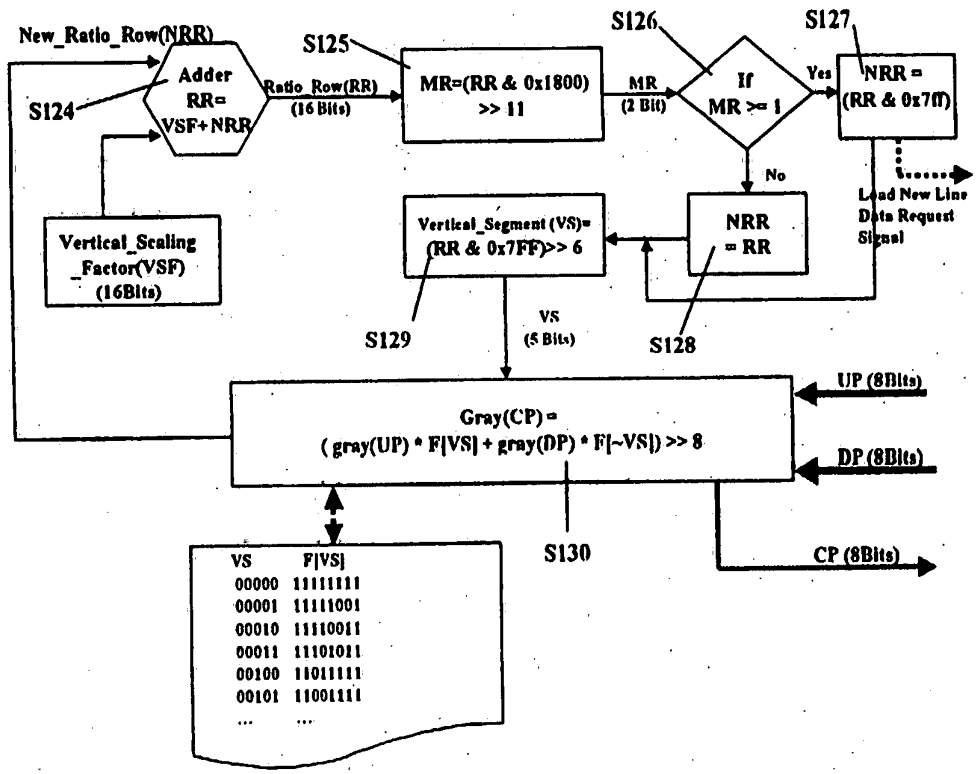

New_Ratio_Row(NRR)
S124
Adder
RR=
VSF+NRR
Vertical_Scaling
_Factor(VSF)
(16Bits)
Ratio_Row(RR)
(16 Bits)
S125
MR=(RR & 0x1800)
>> 11
MR
(2 Bit)
S126
If
MR >= 1
Yes
No
S127
NRR =
(RR & 0x7ff)
Load New Line
Data Request
Signal
NRR
= RR
S128
Vertical_Segment (VS)=
(RR & 0x7FF)>> 6
S129
VS
(5 Bits)
Gray(CP) =
(gray(UP) * F[VS] + gray(DP) * F[~VS]) >> 8
S130
UP (8Bits)
DP (8Bits)
CP (8Bits)
VS
F[VS]
00000 11111111
00001 11111001
00010 11110011
00011 11101011
00100 11011111
00101 11001111
... ...

FIG. 4

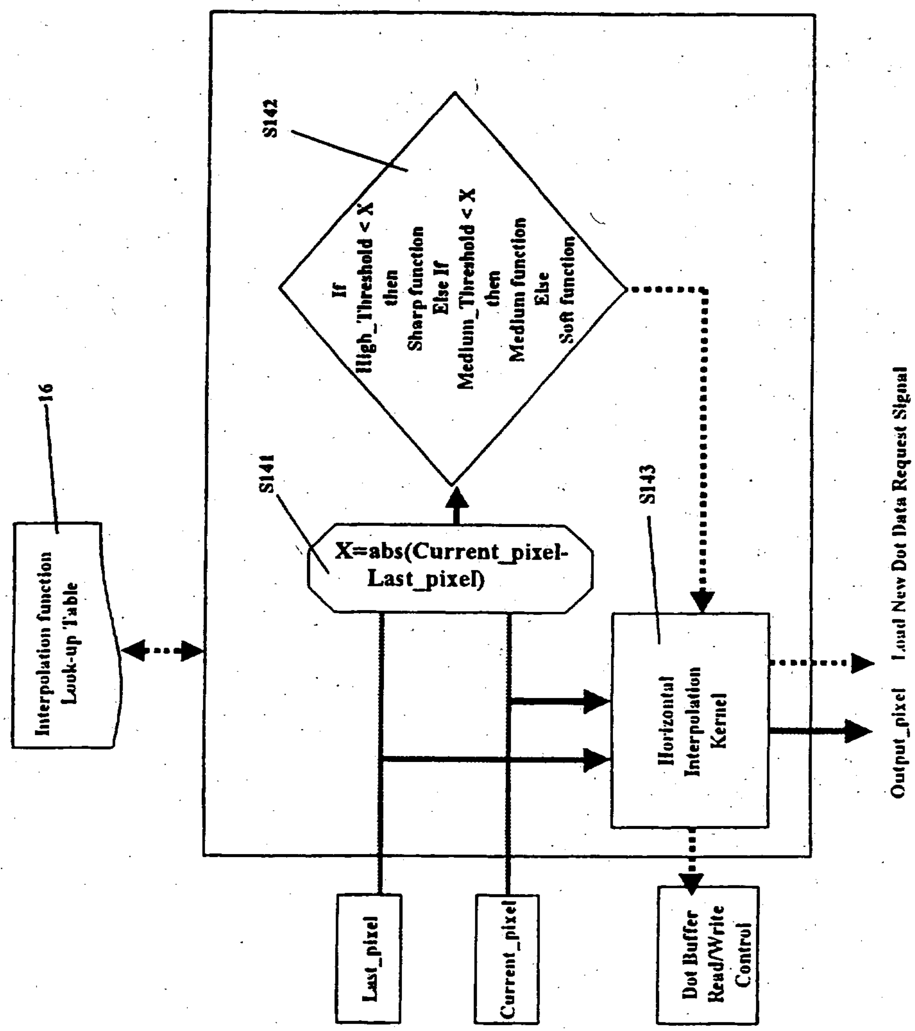

S142
If
High_Threshold < X
then
Sharp function
Else If
Medium_Threshold < X
then
Medium function
Else
Soft function
16
Interpolation function
Look-up Table
S141
X=abs(Current_pixel-
Last_pixel)
S143
Horizontal
Interpolation
Kernel
Load New Dot Data Request Signal
Output_pixel
Last_pixel
Current_pixel
Dot Buffer
Read/Write
Control

FIG. 5

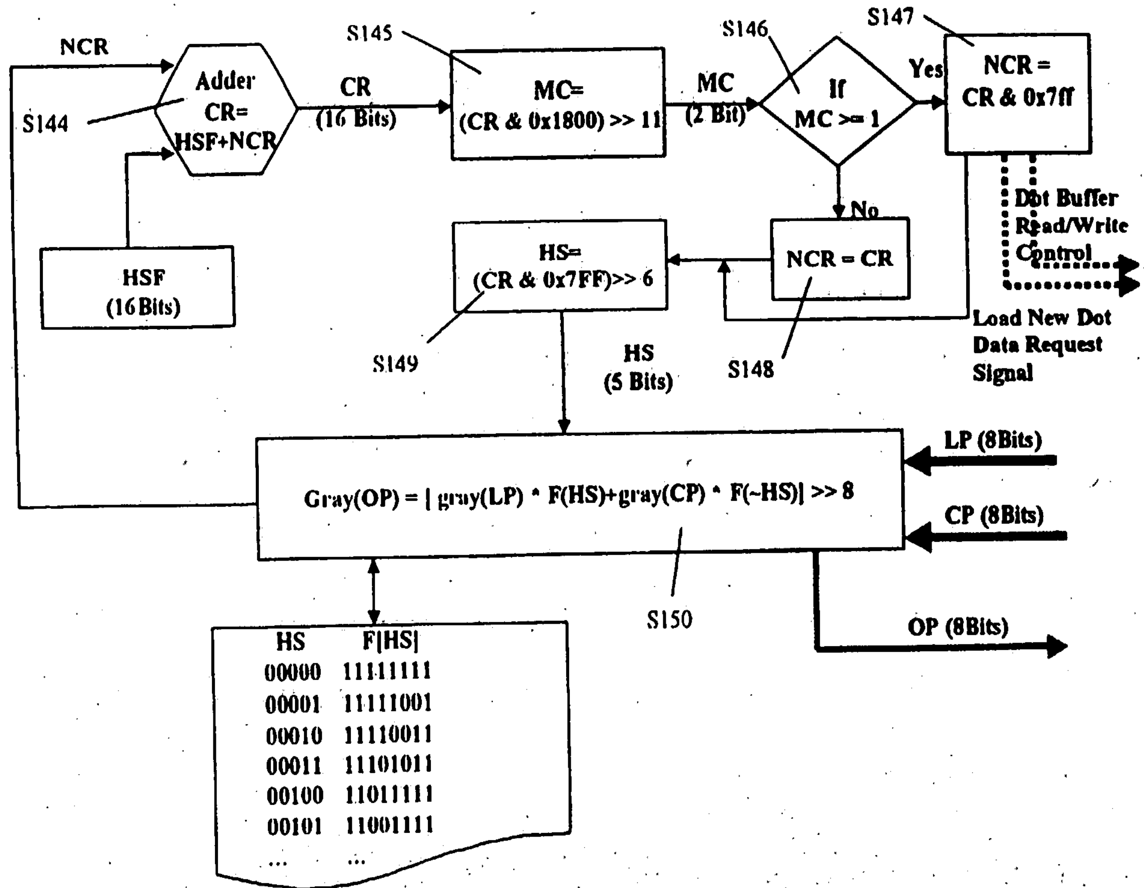

NCR
S144
Adder
CR=
HSF+NCR
HSF
(16 Bits)
CR
(16 Bits)
S145
MC=
(CR & 0x1800) >> 11
MC
(2 Bit)
S146
If
MC >= 1
Yes
No
S147
NCR =
CR & 0x7ff
Dot Buffer
Read/Write
Control
Load New Dot
Data Request
Signal
NCR = CR
S148
HS=
(CR & 0x7FF)>> 6
S149
HS
(5 Bits)
LP (8Bits)
CP (8Bits)
OP (8Bits)
Gray(OP) = | gray(LP) * F(HS)+gray(CP) * F(~HS)| >> 8
S150
HS F[HS]
00000 11111111
00001 11111001
00010 11110011
00011 11101011
00100 11011111
00101 11001111
... ...

FIG. 6

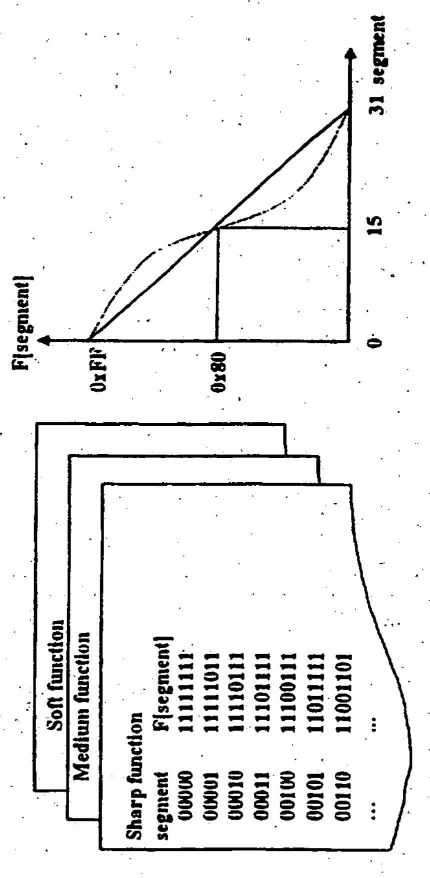
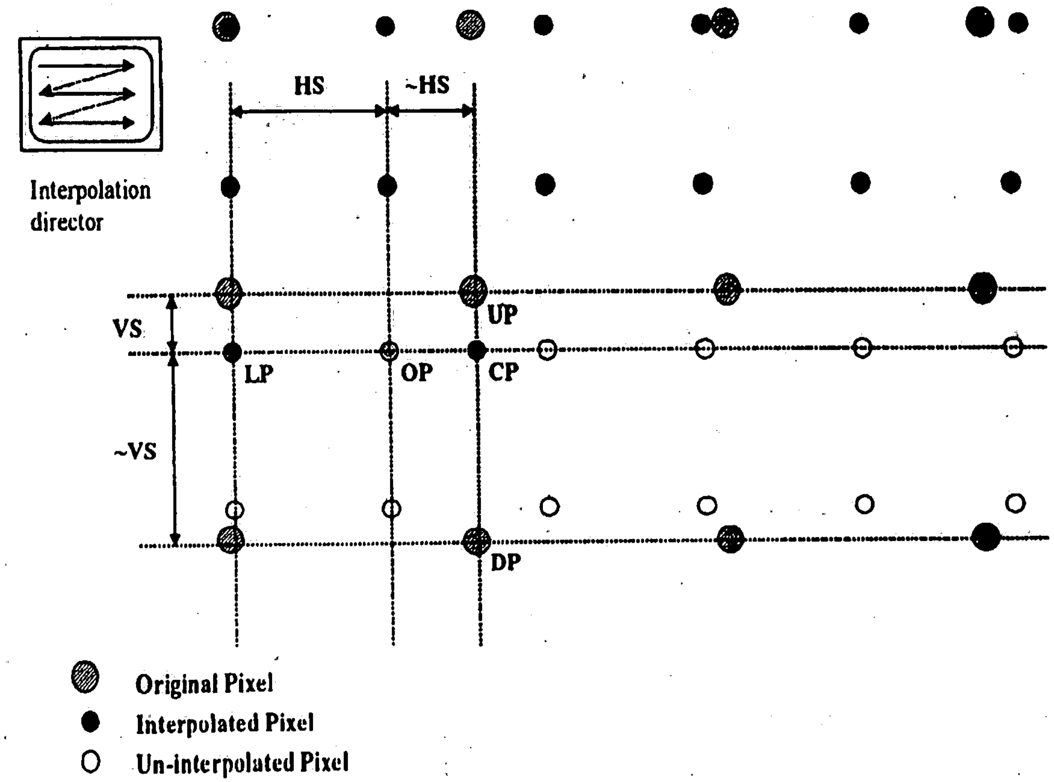
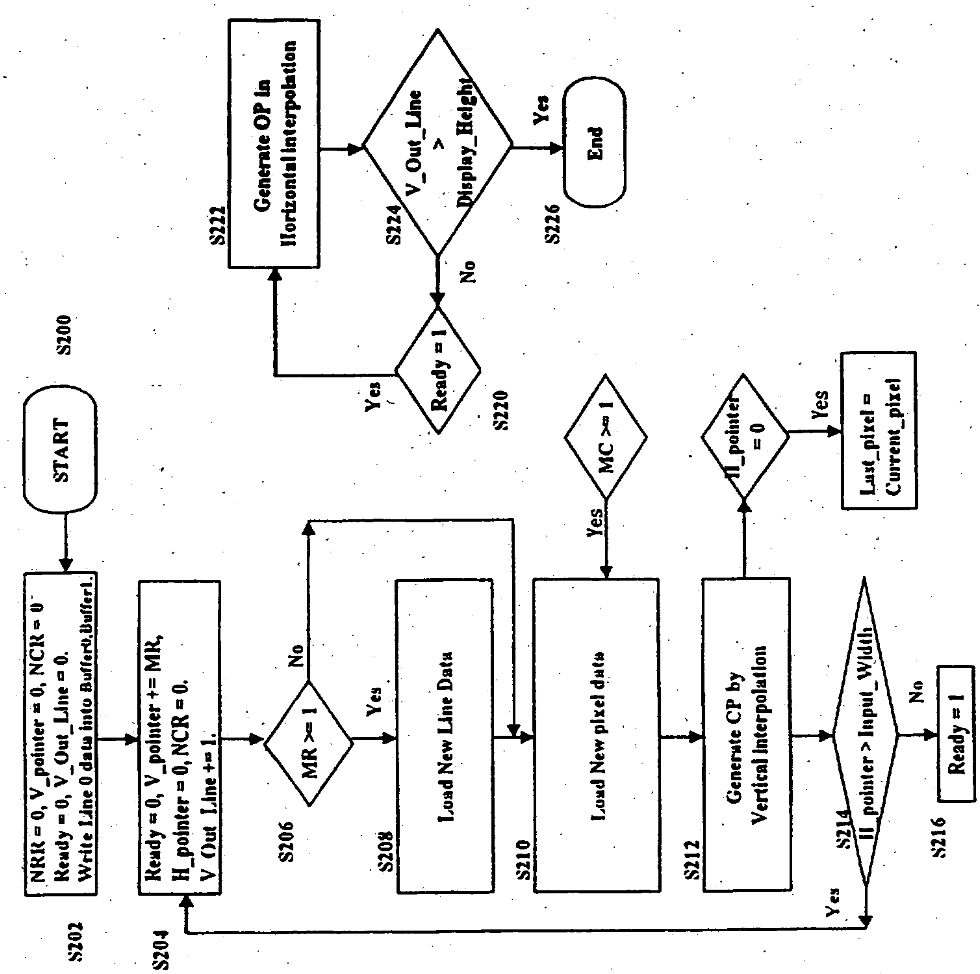

Soft function
Medium function
Sharp function
segment F[segment]
00000 11111111
00001 11111011
00010 11110111
00011 11101111
00100 11100111
00101 11011111
00110 11001101
... ...
F[segment]
0xFF
0x80
0
15
31 segment

FIG. 7



Interpolation director
HS
~HS
VS
~VS
UP
LP
OP
CP
DP
Original Pixel
Interpolated Pixel
Un-interpolated Pixel

FIG. 8



S200
START
S202
NRR = 0, V_pointer = 0, NCR = 0
Ready = 0, V_Out_Line = 0.
Write Line 0 data into Buffer0,Buffer1.
S204
Ready = 0, V_pointer += MR,
H_pointer = 0, NCR = 0.
V_Out_Line += 1.
S206
MR >= 1
No
Yes
S208
Load New Line Data
S210
Load New pixel data
MC >= 1
Yes
S212
Generate CP by
Vertical interpolation
H_pointer
= 0
Yes
Last_pixel =
Current_pixel
S214
H_pointer > Input_Width
Yes
No
S216
Ready = 1
S220
Ready = 1
Yes
S222
Generate OP in
Horizontal interpolation
S224
V_Out_Line
>
Display_Height
No
Yes
S226
End

FIG. 9

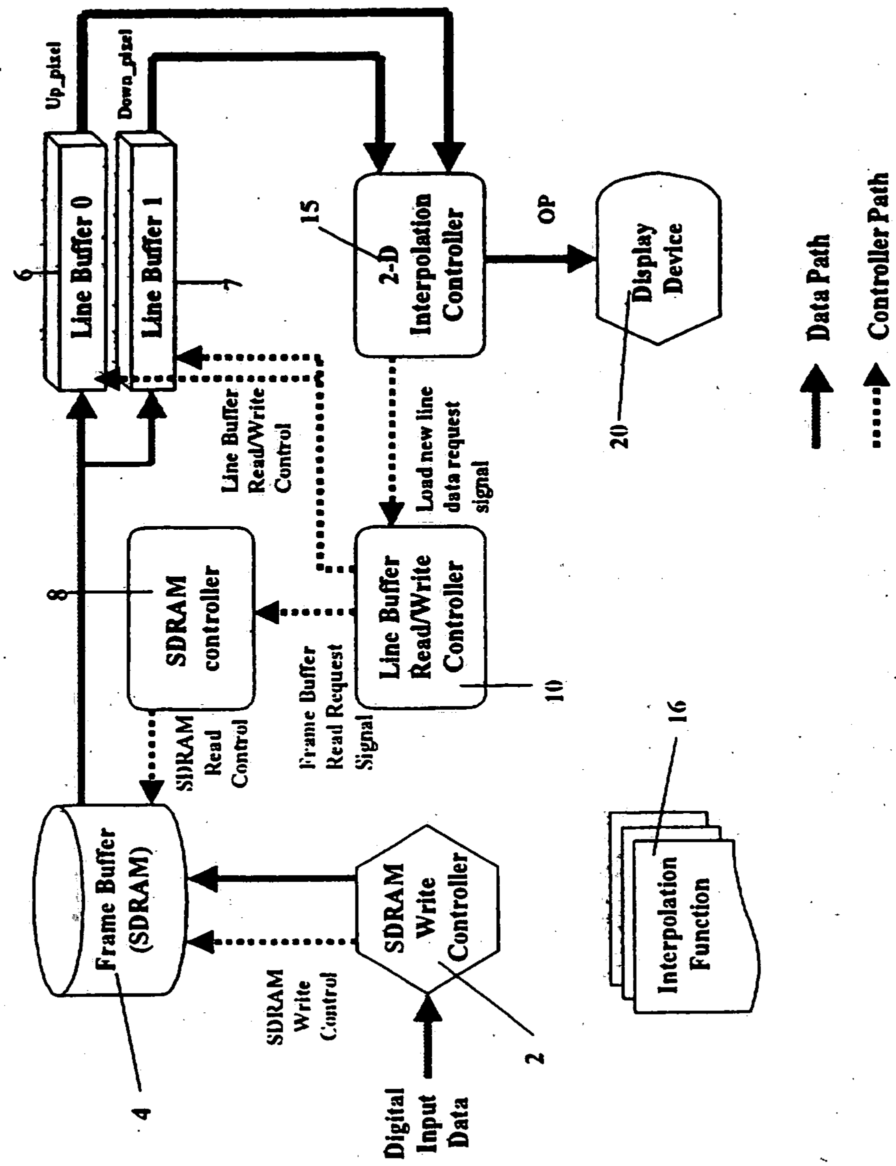

Up_pixel
Down_pixel
Line Buffer 0
Line Buffer 1
6
7
15
2-D Interpolation Controller
OP
Display Device
20
Data Path
Controller Path
8
SDRAM controller
Line Buffer Read/Write Control
Load new line data request signal
Line Buffer Read/Write Controller
10
SDRAM Read Control
Frame Buffer Read Request Signal
16
Frame Buffer (SDRAM)
SDRAM Write Controller
SDRAM Write Control
Interpolation Function
4
2
Digital Input Data

FIG. 10

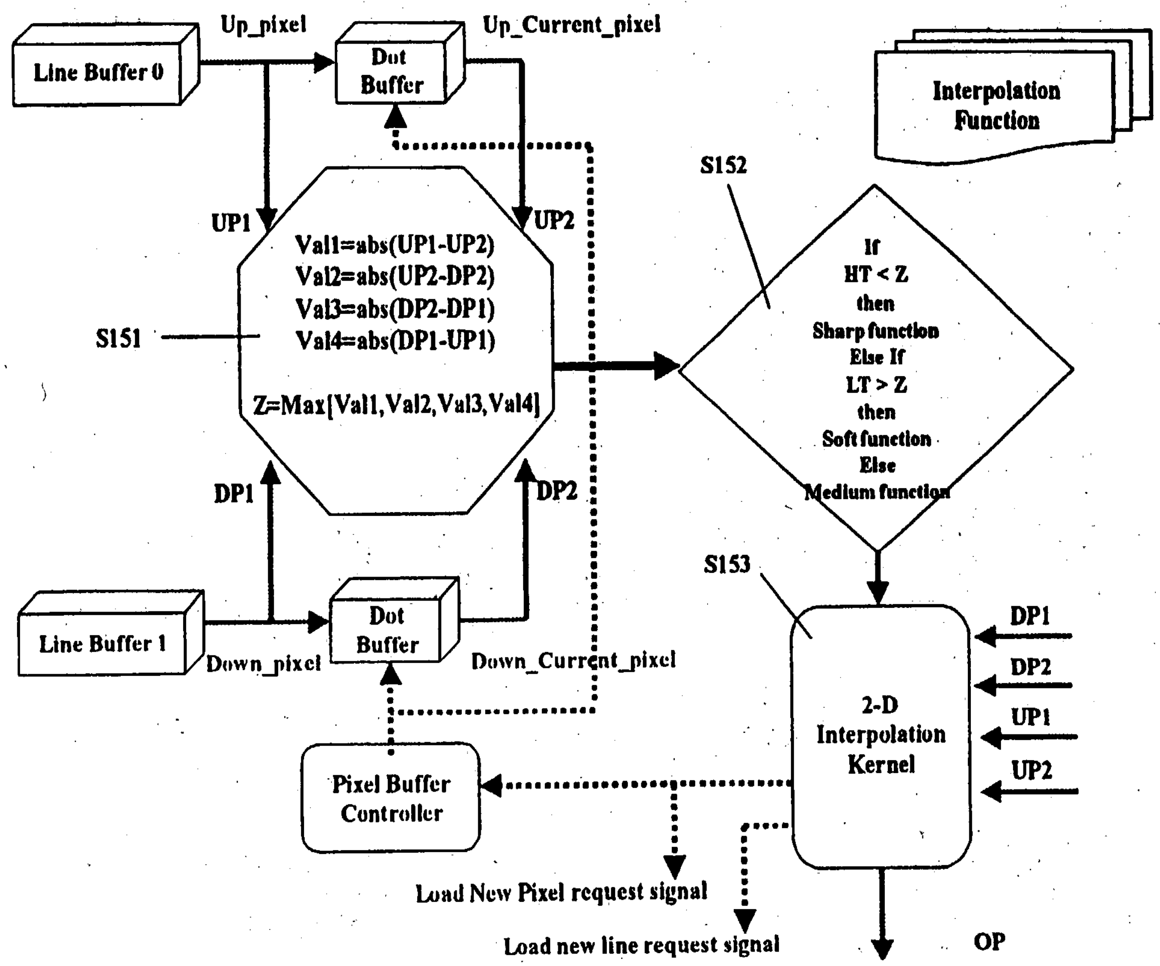

Line Buffer 0
Up_pixel
Dot Buffer
Up_Current_pixel
Interpolation Function
S152
UP1
UP2
Val1=abs(UP1-UP2)
Val2=abs(UP2-DP2)
Val3=abs(DP2-DP1)
Val4=abs(DP1-UP1)
Z=Max[Val1,Val2,Val3,Val4]
S151
If HT < Z then Sharp function Else If LT > Z then Soft function Else Medium function
DP1
DP2
S153
Line Buffer 1
Down_pixel
Dot Buffer
Down_Current_pixel
2-D Interpolation Kernel
DP1
DP2
UP1
UP2
Pixel Buffer Controller
Load New Pixel request signal
Load new line request signal
OP

FIG. 11

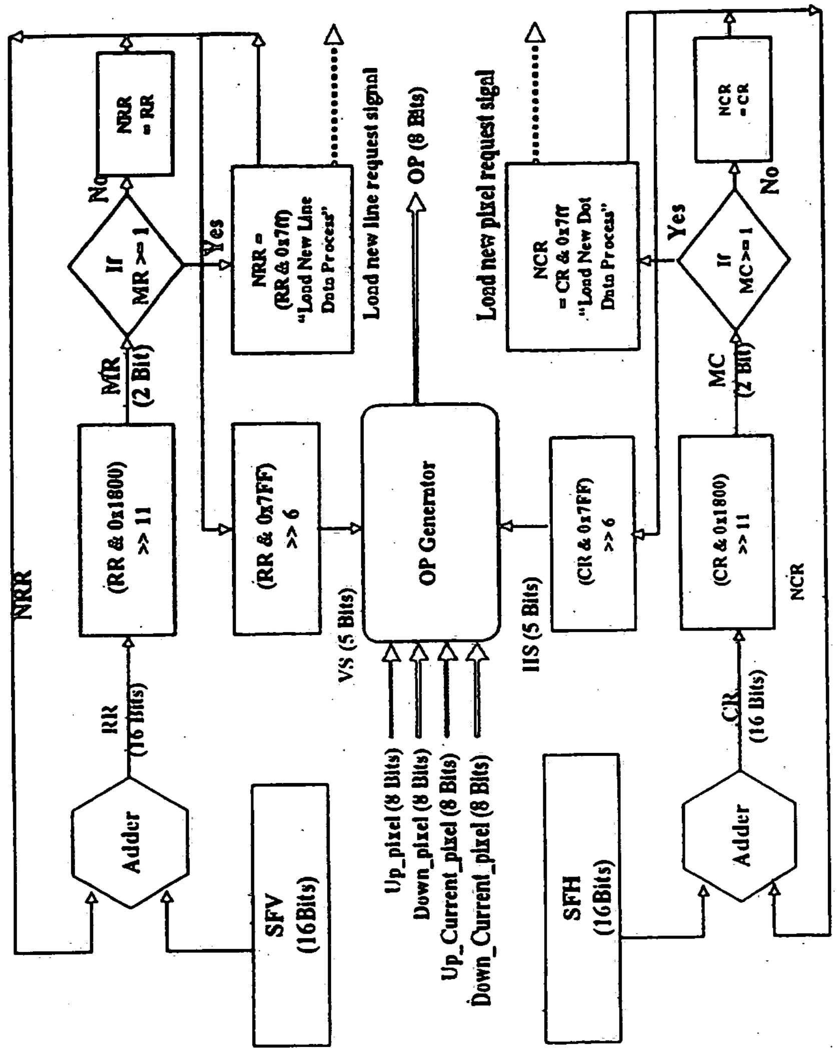

NRR
Adder
SFV (16Bits)
RR (16 Bits)
(RR & 0x1800) >> 11
MR (2 Bit)
If MR >= 1
No
NRR = RR
Yes
NRR = (RR & 0x7ff) "Load New Line Data Process"
Load new line request signal
(RR & 0x7FF) >> 6
VS (5 Bits)
OP Generator
OP (8 Bits)
Up_pixel (8 Bits)
Down_pixel (8 Bits)
Up_Current_pixel (8 Bits)
Down_Current_pixel (8 Bits)
HS (5 Bits)
(CR & 0x7FF) >> 6
Load new pixel request signal
NCR = CR & 0x7ff "Load New Dot Data Process"
SFH (16Bits)
Adder
CR (16 Bits)
(CR & 0x1800) >> 11
MC (2 Bit)
If MC >= 1
Yes
No
NCR = CR
NCR

FIG 12

DIGITAL IMAGE SCALING DEVICE WITH AUTOMATIC IMAGE QUALITY ADJUSTMENT

BACKGROUND OF THE INVENTION

A. Field of the Invention

The present invention relates to a digital image scaling device with automatically adjusting image quality. The scaling device comprises a plurality sets of interpolation functions and is capable of automatically selecting a proper interpolation function therefrom.

B. Description of the Prior Art

A digital display device, such as Liquid Crystal Device (LCD), Digital Micro-mirror Device (DMD), plasma display, is necessary to convert the resolution and frame rate of original image source, if its resolution or image frame rate is different from the original resolution or frame rate. Take a multi-media LCD monitor for an example. The monitor can receive and display original image sources of various resolutions and frame rates, such as the output signals of the computer video cards, including VGA@60, SVGA@75, XGA@85, and SXGA@60, NTSC, PAL, and SECAME signals. The resolution and frame rate converter scales up or scales down the resolution of the original image source and converts the frame rates to display the images on the digital display device. There are already various IC devices embodied with such functions in the market. They are provided by manufacturers, such as Genesis, Paradise, Pixelworks, MXIC, and Arithmos. These IC devices are provided with programmable proportion scaling factors for scaling up or scaling down the resolutions of the original image source and converting the frame rates. Such IC devices play a crucial role in the digital display devices.

Image scaling up or scaling down means to increase or decrease the resolution of the image. In other words, it is an interpolation operation performed on the image. For scaling up an image, it needs to interpolate new pixels to increase its resolution. These new interpolated pixels are inter-related with their neighboring original pixels. The distance can

be the weighting factor of interpolation and defined as interpolation functions. The new interpolated pixels can be computed by a convolution computation based on the interpolation function and the gray level of original pixels. Moreover, based on different interpolation function applied, different image qualities can be obtained.

In the references relating to digital image processing, various interpolation functions, and the relationships between the interpolation errors and the resolution loss of the frequency spectrum for each of the interpolation functions have already been disclosed. Different interpolation functions will cause different interpolation errors and resolution loss and thus generate different image qualities. In general, a first order bilinear interpolation function has been considered as one that can provide a more reasonable trade-off between the interpolation errors and the resolution loss and then generate better results for processing nature image. However, for graphics or text font images, the first order bilinear interpolation function will cause the image to be blurred. In that case, nonlinear interpolation functions may be applied to enhance the picture qualities of graphics or text font images.

However, if a scaling device only employs a single interpolation function for adjusting the resolutions, it cannot be applied to various image types, such as nature image, text font image or graphic. So, after the resolution of the image has been increased, especially when the proportion factors are larger, the nature image will be generated with better effects if a first order bilinear interpolation function is applied. On the other hand, the image of text font image or graphic will be blurred and difficult to see. In contrast, if processed with other interpolation functions, such as a second order non-linear interpolation functions, the text font image or graphic will have better effects for edge-enhancement, but blocking effects will be generated on the nature images.

SUMMARY OF THE INVENTION

Accordingly, it is an object of the present invention to provide a digital image scaling

device which is capable of selecting a corresponding interpolation function from a plurality sets of different int rpolation functions according to the analysis of the original image pixels performed by a function selecting procedure to adjust the image quality and resolve the blurring phenomena.

The digital image scaling device of the present invention can automatically adjust the image qualities by converting digital input image into digital output image of different resolution and frame rate. The scaling device of the present invention includes a memory unit for temporary storing the frame data of the digital input image; a memory access control unit for controlling the writing of digital input image into the memory unit, and the reading of the digital input image data therefrom; a plurality sets of interpolationfunctions for providing various interpolation effects in response to different image quality requests; an interpolation controller for reading a plurality of pixels from the memory unit as referential pixels and for generating digital output image data according to the gray level of the interpolation pixels which can be computed by an interpolation function selected automatically from a plurality sets of interpolation functions using a function selecting procedure and based on the gray level of the referential pixels.

The digital image scaling device with automatic image quality adjustment includes three sets of interpolation function, and each establishes a correspondent look-up table. The three sets of interpolation function include a sharp function, a medium function and a soft function. If the difference of gray level between the referential pixels is larger than a High Threshold, then scaling device selects the sharp function as its interpolation function. If the difference is between the High Threshold and a Low Threshold, then the scaling device selects the medium function as its interpolation function. Otherwise, the scaling device selects the soft function as its interpolation function. Accordingly, the present invention can automatically select a proper interpolation function according to the distribution of the gray level of the original image. Consequently, the blurring or blocking effects of the image can be

successfully resolved.

BRIEF DESCRIPTION OF THE DRAWINGS

These and other objects and advantages of the present invention will become apparent by reference to the following description and accompanying drawings wherein:

FIG. 1 is a system block diagram showing the digital image scaling device with automatic image quality adjustment according to the preferred embodiment of the present invention.

FIG. 2 is a diagram showing the curvatures of the three interpolation functions.

FIG. 3 is a block diagram showing the vertical interpolation controller of the system block diagram as shown in FIG. 1.

FIG. 4 is a data control flowchart of the vertical interpolation controller as shown in FIG. 3.

FIG. 5 is functional block diagram of the horizontal interpolation controller of the system block diagram as shown in FIG. 1.

FIG. 6 is a control flow chart showing the data control flow of the horizontal interpolation controller as shown in FIG. 5.

FIG. 7 is a look-up table for a sharp function for showing an example of the interpolation function table according to the present invention.

FIG. 8 is a schematic diagram showing an example for illustrating the interpolation sequence according to a preferred embodiment of the present invention.

FIG. 9 is an interpolation flowchart for each frame according to the present invention.

FIG. 10 is a system diagram showing the digital image scaling device according to another preferred embodiment of the present invention.

FIG. 11 is a block diagram showing the two dimension interpolation controller as shown in FIG. 10.

FIG. 12 is a block diagram showing the 2-D interpolation kernel.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

A preferred embodiment of the invention is described below. This embodiment is merely exemplary. Those skilled in the art will appreciate that changes can be made to the disclosed embodiment without departing from the spirit and scope of the invention.

Referring to FIG. 1, it shows the system block diagram of the digital image scaling device with automatic image quality adjustment according to a preferred embodiment of the present invention. The scaling device includes a frame buffer 4 for storing the frame data of the original image data, a SDRAM write controller 2 for writing original image data into the frame buffer 4, line buffers 6 and 7, a SDRAM access controller 8 for controlling the reading data from the frame buffer 4 and storing the data into the line buffers 6 and 7, a vertical interpolation controller 12, a horizontal interpolation controller 14, a line buffer read/write controller 10, a interpolation function look-up tables 16 with three interpolationfunctions, and a dot buffer 18. In addition, the output of the horizontal interpolation controller 14 of the scaling device is connected to a display device 20. In the following, the functions of each block will be explained in detail.

The frame buffer 4 is functioning as a buffer between the original image data and output data. Since the frame rate of the original image and that of the display device may be different, so the frame buffer 4 must be embodied with the functions of frame rate conversions. To achieve such a purpose, usually a frame buffer 4 is applied between the input terminal and the output terminal. The embodiment of the present invention is using SDRAM as the frame buffer 4. It is known to those skilled in the art that other types of memories can also be applied.

The SDRAM write controller 2 is for controlling the operation of writing the original image data into the frame buffer 4. The original image data (input signal source) has

multiple formats for the user to choose, such as digitalization of output data of a computer video card and video frequency signal data. After the input signal source is determined, the SDRAM write controller 2 can generate a corresponding control timing signals for writing the frame data into the frame buffer 4.

The line buffers 6 and 7 are for temporary storing two lines of original image data. The line buffer 6 and 7 are for storing the upper and lower line of the image data, respectively. The data in the line buffers 6 and 7 are provided for a vertical interpolation controller 12 as the referential pixels when performing vertical interpolation.

The SDRAM access controller 8 is functioning as an interface for accessing the data from frame buffer 4 (SDRAM). The image frame access request signal of the SDRAM access controller 8 is generated by the line buffer read/write controller 10 described afterwards.

The line buffer read/write controller 10 is for controlling the data access of the line buffers 6 and 7, and for providing a image frame access request signal to the SDRAM access controller 8. The new line data request signal is provided by the vertical interpolation controller 12 described afterwards.

The vertical interpolation controller 12 is for interpolating new pixels in the vertical direction. The vertical interpolation controller 12 reads the data in the line buffer arrays 6, 7 and computes the new pixels, and then sends the new pixels to the dot buffer 18 or the horizontal interpolation controller 14. The detailed operations of the vertical interpolation controller 12 will be explained later.

The dot buffer 18 is for temporarily storing the data from the vertical interpolation controller 12 or from the horizontal interpolation controller 14.

The horizontal interpolation controller 14 is for generating new pixels in the horizontal direction. The horizontal interpolation controller 14 reads the pixels generated by the vertical interpolation controller 12 and the pixel stored in the dot buffer 18, and then generates

th new pixels and sends these pixels to the display device 20. The detailed operations of the horizontal interpolation controller 14 will be explained thereafter.

The interpolation function look-up table 16 stores the data computed according to three different interpolation functions, for example sharp function, medium function, and soft function. An example of the computation results according to the interpolation functions is shown in FIG. 2. The interpolation function look-up table 16 can provide correspondent function values to compute new interpolated pixels by looking up a table for the vertical interpolation controller 12 and the horizontal interpolation controller 14. The advantages for looking up a table is that the designs of the circuitry will be much simpler and the design of the interpolation functions more flexible. Of course, the number of interpolation functions for the look-up table 16 is not limited to three. It can be determined upon practical application.

As illustrated in FIG. 7, it shows an example of the interpolation function look-up table 16 according to the present invention. Each interpolation function is divided into 32 segments and each segments stores a function value with an 8-bits data. The interpolation function look-up table 16 stores each correspondent segment value and its function value. And each interpolation function look-up table can be established using a program.

Then, refer to FIG. 3 and FIG. 4 for illustrating the operations of the vertical interpolation controller 12 according to the present invention. As illustrated in Fig 3, the vertical interpolation controller 12 reads the upper pixel UP and down pixel DP from the line buffers 6 and 7 each time. In addition to sending the pixels to the vertical interpolation kernel S123, it also computes the absolute gray differences Y between the UP and DP according to the formula (1) of step S121, and then sneds Y to the function selecting procedure S122.

$$Y = Abs(UP-DP) \qquad (1)$$

The function selecting procedure S122 determines which interpolation function table to

be selected according to Y for the new pixel to be interpolated. The determination procedure is as foll ws: if Y is larger than the High-Threshold HT, then select the sharp function. If Y is smaller than the Low-Threshold LT, then select the soft function. If Y is between the High-Threshold and the Low-Threshold, then select the medium function. After that, provide the selected interpolation function to the vertical interpolation kernel S123 for computing the new pixels.

In general, the values for the HT and LT are not fixed because they can be adjusted by the users depending on the demanded image qualities. However, for images with 256 gray levels, if the HT and LT are set to be 128 and 80, respectively, then it can generate images of better qualities. For images of different gray levels, different threshold values should be applied.

FIG. 4 shows the operations of the vertical interpolation kernel S123. As illustrated in FIG. 4, the parameters required by the vertical interpolation kernel S123 are New Row Ratio NRR, Vertical Scaling Factor VSF, Up Pixel UP and Down Pixel DP. The initial value of NRR is set as 0 at the time when a new image frame is generated. The VSF is determined according to the Input Height IH of the original image and the Display Height DH, and adjusted as 16 bits data according to the formula (2):

$$VSF = (IH<<11/DH) \qquad (2),$$

wherein "<<" means left-shifting 11 bits of the IH. The purpose of left-shifting IH is to enlarge the value of VSF for the convenience of computation. The number of left-shifted bits is not restricted to 11. It depends on the design of the entire circuitry.

Then, refer to FIG. 4 for illustrating the operations of the vertical interpolation kernel S123.

Step S124: Compute Row Ratio RR, that is, RR=VSF+NRR.

Step S125: Compute the MSB of row ratio, that is, MR=(RR&0X1800) >>11. The number of right-shifted bits is the same as that of the left-shifted bits of the VSF.

Step S126: Compare if the value of MR is larger or equal to 1. If the value is larger or equal to 1, it indicates that the new pixel to be interpolated exceed the margins of the rows in line buffer 6 and 7, so go to step S127. If not, go to step S128.

Step 127: Down load the new row data from the frame buffer 4 to the line buffers 6,7, and assign the decimal value of the Row Ratio RR to the New Row Ratio NRR, that is, NRR=RR&0X7FF, and go to step S129.

Step 128: Assign the Row Ratio RR to the New Row Ratio NRR, that is, NRR=RR, and go to step S129.

Step S129: Compute the Vertical Segment VS, that is, VS=(RR&0X7FF)>>6.

Step S130: Compute the current pixel CP. That is, look for the Interpolation Value IV in the selected interpolation function table according to the Vertical Segment value VS defined by step S129. Compute the gray level of the current pixel CP according to formula (3) and pass the CP to the horizontal interpolation controller 14 and/or the dot buffer 18 as illustrated in FIG. 1. After the entire row has been processed, go to step S124.

$$CP = (UP * IV + DP * \sim IV) >> 8 \qquad (3),$$

Wherein " ~IV" refers to the complementary value of "IV". ">>8" means right-shifting 8 bits. It is because the value of IV is an 8-bits data of a floating point value.

Refer to FIG. 5 and FIG. 6 for illustrating the operations of the horizontal interpolation controller 14 of the present invention. As illustrated in FIG. 5, the horizontal interpolation controller 14 reads the Current Pixel CP from the vertical interpolation controller 12 and Last Pixel LP from dot buffer 18 each time. In addition to sending the pixels to the horizontal interpolation kernel S143, the horizontal interpolation controller 14 computes the absolute gray difference X between the CP and LP according to formula (4) in S141 and sends the X to the function selecting procedure S142.

$$X = Abs(LP-CP) \qquad (4)$$

The function selecting procedure S142 determines which interpolation function table is

to be s lected according to X for the new pixels to be interpolated. The determination procedur is the same as that of vertical interpolation controller 12. So, please refer to the descriptions about the vertical interpolation controller 12 described above. The detailed operations for the function selecting procedure S142 will be omitted.

FIG. 6 shows the operations of the horizontal interpolation kernel S143. As illustrated in FIG. 6, the parameters required by the horizontal interpolation kernel S143 are New Column Ratio NCR, Horizontal Scaling Factor HSF, Current Pixel and Last Pixel. The initial value of NCR is set as 0. The HSF is determined according to the Input Width IW of the original image and the Display Width DW, and adjusted as 16 bits data according to the formula (5).

$$HSF = (IW<<11/DW) \quad (5),$$

wherein, "<<" means left-shifting 11 bits of the IW. The purpose of left-shifting IW is to enlarge the VSF for the convenience of computation. The number of left-shifted bits is not limited to 11. It all depends on the design of the entire circuitry. The computation of HSF is basically the same as that of VSF.

Refer to FIG. 6 for showing the operations of the horizontal interpolation kernel S143.

Step S144: Compute Column Ratio CR, that is, CR=HSF+NCR.

Step S145: Compute the MSB of Column Ratio, that is, MC=(CR&0X1800)>>11. The number of right-shifted bits is the same as that of the left-shifted bits of the HSF.

Step S146: Compare if MC is larger or equal to 1. If it is larger or equal to 1, it indicates that the new pixel to be interpolated exceed the margin of the current pixel CP, so go to step S147. If MC is less than 1, then go to step S148.

Step 147: Read next pixel and assign the decimal value of the Column Ratio CR to the New Row Ratio NRR, that is, NRR=RR&0X7FF.

Step S148: NRR= RR.

Step S149: Compute the horizontal segment HS, that is, HS=(CR&0X7FF)>>6.

Step S150: Compute the output pixel OP. That is, look for the Interpolation Value IV from the selected interpolation function table according to the Horizontal Segment HS defined by step S149. Compute the Output Pixel OP according to formula (6) and send the OP to the display device 20 (as illustrated in FIG. 1), and then go to step S144.

$$OP = (LP * IV + CP * \sim IV) >> 8 \qquad (6),$$

wherein " ~IV" refers to the complementary value of "IV". ">>8" means right-shifting 8 bits. It is because the value of IV is an 8-bit data of a floating point value.

Refer to FIG. 8 and FIG. 9 for showing the interpolation procedures of the present invention. As illustrated in FIG. 8, the interpolation procedure is done row by row and from left to right. The sequence of interpolation is very similar to the scanning sequence for a horizontal scanning and vertical scanning of a display device. As illustrated in FIG. 9, the steps of the interpolation procedure for each image frame are described below:

Step S200: Start.

Step S202: Write the 0^{th} row of the original image data from buffer 4 into the line buffers 6 and 7, and initiate the initial data of the vertical interpolation controller 12, that is, set the value of NRR, Vertical Pointer VP, and Vertical Out Pointer VOP, as 0.

Step S204: Initialize the initial value of the horizontal interpolation controller 14, that is, set the flag (Ready), the NCR, and the Horizontal Pointer HP as 0, and then increase the Vertical Output Pointer by 1.

Step S206: Check the value of MR. If it is larger or equal to 1, then go to step S208. If not, go to step S210.

Step S208: Load new line data. Add MR to VP. That is, VP=VP+MR. Then, load the VP and VP-1 row image data from the frame buffer 4 into the line buffers 6,7 respectively, and go to step S210.

Step S210: Load the new pixels and set the flag Ready as 0. Add MC to HP. That is, HP=HP+MC. Let Last Pixel LP equal to Current Pixel CP, LP = CP. And read the pixels

pointed by the HP from the line buffers 6, 7 as the Up Pixel UP and Down Pixel DP.

St p S212: Compute the Current Pixel CP by the vertical interpolation procedure according to Up Pixel UP and Down Pixel DP. If the HP is 0, then LP = CP.

Step S214: If HP is larger than Input Width IW, then go to step 204. If not, go to step S216.

Step S216: Set the value of flag Ready as 1.

Step S220: If the flag Ready is 1, then go to step S152.

Step S152: Compute the Output Pixel OP by horizontal interpolation procedure based on LP and CP.

Step S224: If the VOP is larger than DH, then go to step S228. If not, go to step S220.

Step S228: stop.

The interpolation procedure as described above is performed in one-dimension. That is, first using the vertical interpolation procedure to interpolate new pixels in each column. Then, using the horizontal interpolation procedure to interpolate Output Pixels based on the new pixels of each column. In addition to one-dimensional interpolation, the interpolation procedures can also be performed in two-dimensional manner to directly compute the Output Pixels. The two-dimensional interpolation procedure is explained as follows.

Refer to FIG. 10, it shows the system diagram of the digital image scaling device with automatic image quality adjustment according to another embodiment of the present invention which performs two-dimensional interpolation. The digital image scaling device comprises a frame buffer 4 for storing image frames; a memory write controller 2 for controlling the data access of the original image data in the frame buffer 4; line buffers 6,7; an access controller 8 for reading data from the frame buffer 4 and storing into line buffers 6,7; a two-dimensional interpolation controller 15; a read/write controller 10 of the line buffers 6,7; and an interpolation function look-up table 16. Moreover, the output of the two-dimensional interpolation controller 15 of the digital image scaling device is connected to the display

device 20.

The embodiment is generally the same as that of the first embodiment. The difference is that the vertical interpolation controller 12 and the horizontal interpolation controller 14 are replaced by a two-dimensional interpolation controller 15. Thus, in the following we will only focus on the two-dimensional interpolation controller 15 for illustrating the spirit of the second embodiment.

Refer to FIG. 11, it shows a functional block diagram of the two-dimensional interpolation controller 15. As illustrated in FIG. 11, the two-dimensional interpolation controller 15 reads two Up Pixels UP1 and UP2, and two Down Pixels DP1 and DP2 from the line buffers 6,7 each time. In addition to sending the pixels to the two-dimensional interpolation kernel S153, it also computes the largest absolute gray difference Z between the UP1, UP2, DP1 and DP2 and sends Z to the function selecting procedure S152. The difference between the gray level can be computed as:

Val1=abs(UP1-UP2)

Val1=abs(UP2-DP2)

Val1=abs(DP2-DP1)

Val1=abs(DP1-UP1)

Z=Max[Val1,Val2,Val3,Val4]

The function selecting procedure S152 selects a proper interpolation function table according to the value of Z. The operations of the function selecting procedure S152 are the same as that of the first embodiment. So, the details is omitted.

Refer to FIG. 12 for showing the functional block diagram of the two-dimensional interpolation kernel S153. As illustrated in FIG. 12, the two-dimensional interpolation kernel S153 includes a vertical segment value computation block at upper part of the drawing and a horizontal segment value computation block at lower part of the drawing. The vertical segment value VSF computation block refers to the vertical segment value of the newly

computed interpolation pixels while the horizontal segment value HSV computation block refers to the horizontal section value of the newly computed interpolation pixels. The computation of the horizontal section and the vertical section are the same as that of the vertical interpolation kernel 12 and horizontal interpolation kernel 14 of the first embodiment, so refer to the description above for the details.

The major difference between the two-dimensional interpolation kernel S153 and the one-dimensional interpolation kernel is in the computation for the Output Pixels. The interpolation performed by the vertical interpolation kernel and the horizontal interpolation kernel as illustrated in FIG. 1 are computed by reference to the pixels of the same row or of the same column. In contrast, the interpolation performed by the two-dimensional interpolation kernel S153 is computed by reference to the four neighboring pixels surrounding the newly interpolated pixel. For this reason, it is called as two-dimensional interpolation. The Output Pixel OP computed by the two-dimensional interpolation kernel S153 can be computed by following formula.

$$UTP = \{UP1*F(HSV) + UP2*\sim F(HSV)\} >> 8,$$

$$DTP = \{DP1*F(HSV) + DP2*\sim F(HSV)\} >> 8,$$

$$OP = \{UTP*F(VSV) + DTP*\sim F(VSV)\} >> 8,$$

wherein, UP1, UP2, DP1 and DP2 representing the upper left side and upper right side, lower left side and lower right side of the Output Pixel.

The two-dimensional interpolation procedure is similar to that as illustrated in FIG. 9. The difference between the one-dimensional interpolation procedure and the two-dimensional interpolation procedure is in the computation for the Output Point. The detailed description is omitted.

The digital image scaling device with automatic image quality adjustment includes a plurality of interpolation function tables. A function selecting procedure automatically selects a set of interpolation functions for interpolation, thereby to improve the blurring or

block effects of the images to improve the image quality.

The digital image scaling device with automatic image quality adjustment has been described in detail hereinabove. It is to be understood that he scope of the invention also comprehends embodiments different from the one described, yet within the scope of the claims. For example, the interpolation function look-up table 16 as provided in the preferred embodiment is divided into 32 segments each segment being correspondent to an 8-bit data of a floating point value. However, it could also be divided into 64 segments each correspondent to a 10-bit data of a floating point value.

It should be understood that various alternatives to the structures described herein may be employed in practicing the present invention. It is intended that the following claims define the invention and that the structure within the scope of these claims and their equivalents be covered thereby.

CLAIMS

1. A digital image scaling device with automatic image quality adjustment for converting a resolution of original digital image into a different resolution, and converting a frame rate of said original digital image into a different frame rate, said digital image scaling device comprising:

memory buffer for temporally storing frame data of said original digital image;

memory access controller for controlling data access of said memory buffer;

a plurality of interpolation functions for providing various interpolation effects;

a interpolation controller for interpolating new pixels, said interpolation controller reading a plurality of pixels from said memory buffer as referential pixels, selecting one interpolation function as selected interpolation function from said plurality of interpolation functions based on gray level of said referential pixels by a function selecting procedure, and computing said new pixels according to said selected interpolation function.

2. The digital image scaling device with automatic image quality adjustment as claimed in

claim 1, further comprising:

a plurality of line buffers for storing line data and being the buffer between said memory buffer and said interpolation controller; and

a read/write controller for controlling data access of said plurality of line buffers.

3. The digital image scaling device with automatic image quality adjustment as claimed in claim 1, wherein said interpolation controller comprises a vertical interpolation controller and a horizontal interpolation controller.

4. The digital image scaling device with automatic image quality adjustment as claimed in claim 3, wherein said vertical interpolation controller loads two pixels from neighboring two rows of said original digital image as said referential pixels, and generates a interpolation pixel each time.

5. The digital image scaling device with automatic image quality adjustment as claimed in claim 4, wherein said horizontal interpolation controller loads two pixels from the neighboring interpolation pixels generated from said vertical interpolation controller as referential pixels, and generates said new pixel each time.

6. The digital image scaling device with automatic image quality adjustment as claimed in claim 1, wherein said interpolation controller is a two-dimensional interpolation controller.

7. The digital image scaling device with automatic image quality adjustment as claimed in claim 6, wherein said two-dimensional interpolation controller loads four pixels from said neighboring rows of said original digital image as said referential pixels, and generates said new pixel each time.

8. The digital image scaling device with automatic image quality adjustment as claimed in claim 1, wherein said plurality sets of interpolation function comprise a sharp function, a medium function, and a soft function.

9. The digital image scaling device with automatic image quality adjustment as claimed in

claim 8, wherein said plurality of interpolation functions each establishes a look-up table.

10. The digital image scaling device with automatic image quality adjustment as claimed in claim 8, wherein said function selecting procedure comprises the steps of:

if the difference of gray level between said referential pixels is larger than a High Threshold, selecting said sharp function;

else if said difference is smaller than said High Threshold and larger than a Low Threshold, selecting said medium function;

else selecting said soft function.

11. A digital image scaling method with automatic image quality adjustment for converting resolution and frame rate of original digital image into different resolution and frame rate, comprising the steps of:

storing frame data of said original digital image into a memory buffer;

reading a plurality of referential pixels from said memory buffer;

computing the difference of gray level between said plurality of referential pixels;

selecting an interpolation function as a selected interpolation function from a plurality of interpolation functions by a function selecting procedure according to said difference ; and

computing new pixel according to said plurality of referential pixels and said selected interpolationfunction.

12. The digital image scaling method with automatic image quality adjustment as claimed in claim 11, wherein said plurality of interpolationfunctions comprise a sharp function, a medium function, and a soft function.

13. The digital image scaling method with automatic image quality adjustment as claimed in claim 12, wherein said function selecting procedure comprises the steps of:

if said difference is larger than a High Threshold, selecting said sharp function;

else if said difference is smaller than said High Threshold and larger than a Low

Threshold, selecting said medium function;

else selecting said soft function.

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Claims searched:	All	**Date of search:**	11 October 2000

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Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.R): H4T(TCGK); H4F(FESK, FGXE)

Int Cl (Ed.7): G06T(3/40)

Other: Online: WPI, EPODOC, JAPIO

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
X	EP 0814429A2	(Quantel) - see abstract	1,11
X	EP 0789325A2	(Adobe Systems) - see abstract	1,11
X	WO 96/16380A1	(Minesota Mining & Mfg) - see abstract	1,11
X	WO 90/16034A1	(Eastman Kodak) - see abstract	1,11
X	US 5832142	(Fuji Photo Film) - see abstract	1,11
X	US 5054100	(Eastman Kodak) - see abstract	1,11

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